

## APPENDIX A: LINK BUDGET

This appendix contains data from link calculations for both the low-end and high-end receiving systems. The receiving systems are defined by the receiver noise figures and antennas described in Section 2 of this report. The transmitter and receiver losses are assumed to include antenna circuit losses, polarization mismatch, and transmission line losses. Modulator/demodulator losses are given in Section 5 and are included in the required CNR.

Tables A-1 through A-4 give the link budget data for various noise environments and receiving systems. The first column of numbers in the link budget corresponds to a 5-W spacecraft (S/C) transmitter and the second column corresponds to a 15-W S/C transmitter. The antenna temperature and system temperature correspond to the definitions given in Section 2 of this report.

Figures A-1 through A-8 give the cumulative distributions (with respect to time) of the received CNR for high-end and low-end systems in various noise environments. The threshold levels required for both DEBPSK and DEQPSK modulation are included in the figures. In each figure, there are four curves corresponding to two elevation angles and two transmitter powers  $P_t$ . The upper two curves are for an elevation of  $90^\circ$  (15-W and 5-W transmitter power) and the lower two curves are for an elevation of  $5^\circ$  and the same two transmitter power levels.

**Table A-1. Link Budget for the Low-end System and 90° Satellite Elevation**

<b>S/C Transmitting RF Channel Performance</b>			
Transmitter power	(dBW)	7.0	11.8
Antenna gain	(dB)	3.7	3.7
Antenna circuit loss	(dB)	2.2	2.2
EIRP	(dBW)	8.5	13.3
<b>Space-to-Earth Path Performance</b>			
Path length	(km)	824.0	824.0
Free space loss	(dB)	133.5	133.5
Atmospheric Attenuation	(dB)	.0	.0
Ionospheric Attenuation	(dB)	.0	.0
<b>E/S Receiving RF Channel Performance</b>			
Antenna gain	(dB)	3.2	3.2
Antenna circuit loss	(dB)	2.0	2.0
Receiver noise figure	(dB)	6.0	6.0
Receiver temperature	(K)	8.6E+02	8.6E+02
Received carrier power	(dBW)	-121.8	-117.0
Receiver bandwidth	(dB-Hz)	48.6	48.6
Boltzmann const	(dB W/K/Hz)	-228.6	-228.6
<b>Required CNR</b>			
DEBPSK	(dB)	8.5	8.5
DEQPSK	(dB)	5.8	5.8
<b>Man-made noise environments for 99.8% time availability</b>			
<b>Business</b>			
Antenna temperature	(K)	2.5E+06	2.5E+06
System temperature	(K)	2.5E+06	2.5E+06
System noise power	(dBW)	-116.0	-116.0
Received CNR	(dB)	-5.8	-1.0
DEBPSK margin	(dB)	-14.3	-9.5
DEQPSK margin	(dB)	-11.6	-6.8
<b>Residential</b>			
Antenna temperature	(K)	9.4E+05	9.4E+05
System temperature	(K)	9.4E+05	9.4E+05
System noise power	(dBW)	-120.3	-120.3
Received CNR	(dB)	-1.5	3.3
DEBPSK margin	(dB)	-10.0	-5.2
DEQPSK margin	(dB)	-7.3	-2.5
<b>Rural</b>			
Antenna temperature	(K)	2.8E+05	2.8E+05
System temperature	(K)	2.8E+05	2.8E+05
System noise power	(dBW)	-125.6	-125.6
Received CNR	(dB)	3.8	8.6
DEBPSK margin	(dB)	-4.7	.1
DEQPSK margin	(dB)	-2.0	2.8
<b>Quiet Rural</b>			
Antenna temperature	(K)	7.8E+03	7.8E+03
System temperature	(K)	9.3E+03	9.3E+03
System noise power	(dBW)	-140.3	-140.3
Received CNR	(dB)	18.6	23.3

Table A-1. Continued

DEBPSK margin	(dB)	10.1	14.8
DEQPSK margin	(dB)	12.8	17.5
<b>Man-made noise environments for 90.0% time availability</b>			
<b>Business</b>			
Antenna temperature	(K)	1.6E+05	1.6E+05
System temperature	(K)	1.6E+05	1.6E+05
System noise power	(dBW)	-128.0	-128.0
Received CNR	(dB)	6.3	11.1
DEBPSK margin	(dB)	-2.2	2.6
DEQPSK margin	(dB)	.5	5.3
<b>Residential</b>			
Antenna temperature	(K)	5.8E+04	5.8E+04
System temperature	(K)	5.9E+04	5.9E+04
System noise power	(dBW)	-132.3	-132.3
Received CNR	(dB)	10.5	15.3
DEBPSK margin	(dB)	2.0	6.8
DEQPSK margin	(dB)	4.7	9.5
<b>Rural</b>			
Antenna temperature	(K)	1.7E+04	1.7E+04
System temperature	(K)	1.9E+04	1.9E+04
System noise power	(dBW)	-137.2	-137.2
Received CNR	(dB)	15.5	20.3
DEBPSK margin	(dB)	7.0	11.8
DEQPSK margin	(dB)	9.7	14.5
<b>Quiet Rural</b>			
Antenna temperature	(K)	1.0E+03	1.0E+03
System temperature	(K)	2.6E+03	2.6E+03
System noise power	(dBW)	-145.9	-145.9
Received CNR	(dB)	24.2	28.9
DEBPSK margin	(dB)	15.7	20.4
DEQPSK margin	(dB)	18.4	23.1

**Table A-2. Link Budget for the Low-end System and 13° Satellite Elevation**

<b>S/C Transmitting RF Channel Performance</b>			
Transmitter power	(dBW)	7.0	11.8
Antenna gain	(dB)	.0	.0
Antenna circuit loss	(dB)	2.2	2.2
EIRP	(dBW)	4.8	9.6
<b>Space-to-Earth Path Performance</b>			
Path length	(km)	2207.5	2207.5
Free space loss	(dB)	142.1	142.1
Atmospheric Attenuation	(dB)	.0	.0
Ionospheric Attenuation	(dB)	.0	.0
<b>E/S Receiving RF Channel Performance</b>			
Antenna gain	(dB)	.4	.4
Antenna circuit loss	(dB)	2.0	2.0
Receiver noise figure	(dB)	6.0	6.0
Receiver temperature	(K)	8.6E+02	8.6E+02
Received carrier power	(dBW)	-136.8	-132.1
Receiver bandwidth	(dB-Hz)	48.6	48.6
Boltzmann const	(dB W/K/Hz)	-228.6	-228.6
<b>Required CNR</b>			
DEBPSK	(dB)	8.5	8.5
DEQPSK	(dB)	5.8	5.8
<b>Man-made noise environments for 99.8% time availability</b>			
<b>Business</b>			
Antenna temperature	(K)	2.5E+06	2.5E+06
System temperature	(K)	2.5E+06	2.5E+06
System noise power	(dBW)	-116.0	-116.0
Received CNR	(dB)	-20.8	-16.1
DEBPSK margin	(dB)	-29.3	-24.6
DEQPSK margin	(dB)	-26.6	-21.9
<b>Residential</b>			
Antenna temperature	(K)	9.4E+05	9.4E+05
System temperature	(K)	9.4E+05	9.4E+05
System noise power	(dBW)	-120.3	-120.3
Received CNR	(dB)	-16.5	-11.8
DEBPSK margin	(dB)	-25.0	-20.3
DEQPSK margin	(dB)	-22.3	-17.6
<b>Rural</b>			
Antenna temperature	(K)	2.8E+05	2.8E+05
System temperature	(K)	2.8E+05	2.8E+05
System noise power	(dBW)	-125.6	-125.6
Received CNR	(dB)	-11.2	-6.5
DEBPSK margin	(dB)	-19.7	-15.0
DEQPSK margin	(dB)	-17.0	-12.3
<b>Quiet Rural</b>			
Antenna temperature	(K)	7.8E+03	7.8E+03
System temperature	(K)	9.3E+03	9.3E+03
System noise power	(dBW)	-140.3	-140.3
Received CNR	(dB)	3.5	8.3

**Table A-2. Continued**

DEBPSK margin	(dB)	-5.0	-.2
DEQPSK margin	(dB)	-2.3	2.5
<b>Man-made noise environments for 90.0% time availability</b>			
<b>Business</b>			
Antenna temperature	(K)	1.6E+05	1.6E+05
System temperature	(K)	1.6E+05	1.6E+05
System noise power	(dBW)	-128.0	-128.0
Received CNR	(dB)	-8.8	-4.0
DEBPSK margin	(dB)	-17.3	-12.5
DEQPSK margin	(dB)	-14.6	-9.8
<b>Residential</b>			
Antenna temperature	(K)	5.8E+04	5.8E+04
System temperature	(K)	5.9E+04	5.9E+04
System noise power	(dBW)	-132.3	-132.3
Received CNR	(dB)	-4.5	.2
DEBPSK margin	(dB)	-13.0	-8.3
DEQPSK margin	(dB)	-10.3	-5.6
<b>Rural</b>			
Antenna temperature	(K)	1.7E+04	1.7E+04
System temperature	(K)	1.9E+04	1.9E+04
System noise power	(dBW)	-137.2	-137.2
Received CNR	(dB)	.4	5.2
DEBPSK margin	(dB)	-8.1	-3.3
DEQPSK margin	(dB)	-5.4	-.6
<b>Quiet Rural</b>			
Antenna temperature	(K)	1.0E+03	1.0E+03
System temperature	(K)	2.6E+03	2.6E+03
System noise power	(dBW)	-145.9	-145.9
Received CNR	(dB)	9.1	13.9
DEBPSK margin	(dB)	.6	5.4
DEQPSK margin	(dB)	3.3	8.1

**Table A-3. Link Budget for the High-end System and 90° Satellite Elevation**

<b>S/C Transmitting RF Channel Performance</b>			
Transmitter power	(dBW)	7.0	11.8
Antenna gain	(dB)	3.7	3.7
Antenna circuit loss	(dB)	2.2	2.2
EIRP	(dBW)	8.5	13.3
<b>Space-to-Earth Path Performance</b>			
Path length	(km)	824.0	824.0
Free space loss	(dB)	133.5	133.5
Atmospheric attenuation	(dB)	.0	.0
Ionospheric attenuation	(dB)	.0	.0
<b>E/S Receiving RF Channel Performance</b>			
Antenna gain	(dB)	10.0	10.0
Antenna circuit loss	(dB)	2.0	2.0
Receiver noise figure	(dB)	1.0	1.0
Receiver temperature	(K)	7.5E+01	7.5E+01
Received carrier power	(dBW)	-115.0	-110.2
Receiver bandwidth	(dB-Hz)	48.6	48.6
Boltzmann const	(dB W/K/Hz)	-228.6	-228.6
<b>Required CNR</b>			
DEBPSK	(dB)	8.5	8.5
DEQPSK	(dB)	5.8	5.8
<b>Man-made noise environments 99.8% time availability</b>			
<b>Business</b>			
Antenna temperature	(K)	8.6E+05	8.6E+05
System temperature	(K)	8.6E+05	8.6E+05
System noise power	(dBW)	-120.7	-120.7
Received CNR	(dB)	5.7	10.5
DEBPSK margin	(dB)	-2.8	2.0
DEQPSK margin	(dB)	-.1	4.7
<b>Residential Noise</b>			
Antenna temperature	(K)	3.2E+05	3.2E+05
System temperature	(K)	3.2E+05	3.2E+05
System noise power	(dBW)	-125.0	-125.0
Received CNR	(dB)	10.0	14.8
DEBPSK margin	(dB)	1.5	6.3
DEQPSK margin	(dB)	4.2	9.0
<b>Rural</b>			
Antenna temperature	(K)	9.4E+04	9.4E+04
System temperature	(K)	9.4E+04	9.4E+04
System noise power	(dBW)	-130.2	-130.2
Received CNR	(dB)	15.3	20.0
DEBPSK margin	(dB)	6.8	11.5
DEQPSK margin	(dB)	9.5	14.2
<b>Quiet Rural</b>			
Antenna temperature	(K)	2.7E+03	2.7E+03
System temperature	(K)	2.9E+03	2.9E+03
System noise power	(dBW)	-145.3	-145.3
Received CNR	(dB)	30.3	35.1

Table A-3. Continued

DEBPSK margin	(dB)	21.8	26.6
DEQPSK margin	(dB)	24.5	29.3
<b>Man-made noise environments 90.0% time availability</b>			
<b>Business</b>			
Antenna temperature	(K)	5.3E+04	5.3E+04
System temperature	(K)	5.3E+04	5.3E+04
System noise power	(dBW)	-132.7	-132.7
Received CNR	(dB)	17.8	22.5
DEBPSK margin	(dB)	9.3	14.0
DEQPSK margin	(dB)	12.0	16.7
<b>Residential</b>			
Antenna temperature	(K)	2.0E+04	2.0E+04
System temperature	(K)	2.0E+04	2.0E+04
System noise power	(dBW)	-137.0	-137.0
Received CNR	(dB)	22.0	26.8
DEBPSK margin	(dB)	13.5	18.3
DEQPSK margin	(dB)	16.2	21.0
<b>Rural</b>			
Antenna temperature	(K)	5.9E+03	5.9E+03
System temperature	(K)	6.2E+03	6.2E+03
System noise power	(dBW)	-142.1	-142.1
Received CNR	(dB)	27.1	31.9
DEBPSK margin	(dB)	18.6	23.4
DEQPSK margin	(dB)	21.3	26.1
<b>Quiet Rural</b>			
Antenna temperature	(K)	3.5E+02	3.5E+02
System temperature	(K)	6.4E+02	6.4E+02
System noise power	(dBW)	-152.0	-152.0
Received CNR	(dB)	37.0	41.7
DEBPSK margin	(dB)	28.5	32.5
DEQPSK margin	(dB)	31.2	35.9

**Table A-4. Link Budget for the High-end System and 5° Satellite Elevation**

<b>S/C Transmitting RF Channel Performance</b>			
Transmitter power	(dBW)	7.0	11.8
Antenna gain	(dB)	-.3	-.3
Antenna circuit loss	(dB)	2.2	2.2
EIRP	(dBW)	4.5	9.3
<b>Space-to-Earth Path Performance</b>			
Path length	(km)	2833.3	2833.3
Free Space Loss	(dB)	144.2	144.2
Atmospheric attenuation	(dB)	.0	.0
Ionospheric attenuation	(dB)	.0	.0
<b>E/S Receiving RF Channel Performance</b>			
Antenna gain	(dB)	10.0	10.0
Antenna circuit loss	(dB)	2.0	2.0
Receiver noise figure	(dB)	1.0	1.0
Receiver temperature	(K)	7.5E+01	7.5E+01
Received carrier power	(dBW)	-129.7	-125.0
Receiver bandwidth	(dB-Hz)	48.6	48.6
Boltzmann const	(dB W/K/Hz)	-228.6	-228.6
<b>Required CNR</b>			
DEBPSK	(dB)	8.5	8.5
DEQPSK	(dB)	5.8	5.8
<b>Man-made noise environments 99.8% time availability</b>			
<b>Business</b>			
Antenna temperature	(K)	8.0E+06	8.0E+06
System temperature	(K)	8.0E+06	8.0E+06
System noise power	(dBW)	-111.0	-111.0
Received CNR	(dB)	-18.7	-14.0
DEBPSK margin	(dB)	-27.2	-22.5
DEQPSK margin	(dB)	-24.5	-19.8
<b>Residential Noise</b>			
Antenna temperature	(K)	3.0E+06	3.0E+06
System temperature	(K)	3.0E+06	3.0E+06
System noise power	(dBW)	-115.3	-115.3
Received CNR	(dB)	-14.4	-9.7
DEBPSK margin	(dB)	-22.9	-18.2
DEQPSK margin	(dB)	-20.2	-15.5
<b>Rural</b>			
Antenna temperature	(K)	8.8E+05	8.8E+05
System temperature	(K)	8.8E+05	8.8E+05
System noise power	(dBW)	-120.6	-120.6
Received CNR	(dB)	-9.1	-4.4
DEBPSK margin	(dB)	-17.6	-12.9
DEQPSK margin	(dB)	-14.9	-10.2
<b>Quiet Rural</b>			
Antenna temperature	(K)	2.5E+04	2.5E+04
System temperature	(K)	2.5E+04	2.5E+04
System noise power	(dBW)	-136.0	-136.0
Received CNR	(dB)	6.3	11.1



Table A-4. Continued

DEBPSK margin	(dB)	-2.2	2.6
DEQPSK margin	(dB)	.5	5.3
<b>Man-made noise environments 90.0% time availability</b>			
<b>Business</b>			
Antenna temperature	(K)	4.9E+05	4.9E+05
System temperature	(K)	4.9E+05	4.9E+05
System noise power	(dBW)	-123.1	-123.1
Received CNR	(dB)	-6.6	-1.9
DEBPSK margin	(dB)	-15.1	-10.4
DEQPSK margin	(dB)	-12.4	-7.7
<b>Residential</b>			
Antenna temperature	(K)	1.8E+05	1.8E+05
System temperature	(K)	1.8E+05	1.8E+05
System noise power	(dBW)	-127.4	-127.4
Received CNR	(dB)	-2.3	2.4
DEBPSK margin	(dB)	-10.8	-6.1
DEQPSK margin	(dB)	-8.1	-3.4
<b>Rural</b>			
Antenna temperature	(K)	5.5E+04	5.5E+04
System temperature	(K)	5.5E+04	5.5E+04
System noise power	(dBW)	-132.6	-132.6
Received CNR	(dB)	2.9	7.6
DEBPSK margin	(dB)	-5.6	-.9
DEQPSK margin	(dB)	-2.9	1.8
<b>Quiet Rural</b>			
Antenna temperature	(K)	3.3E+03	3.3E+03
System temperature	(K)	3.6E+03	3.6E+03
System noise power	(dBW)	-144.5	-144.5
Received CNR	(dB)	14.8	19.6
DEBPSK margin	(dB)	6.3	11.1
DEQPSK margin	(dB)	9.0	13.8

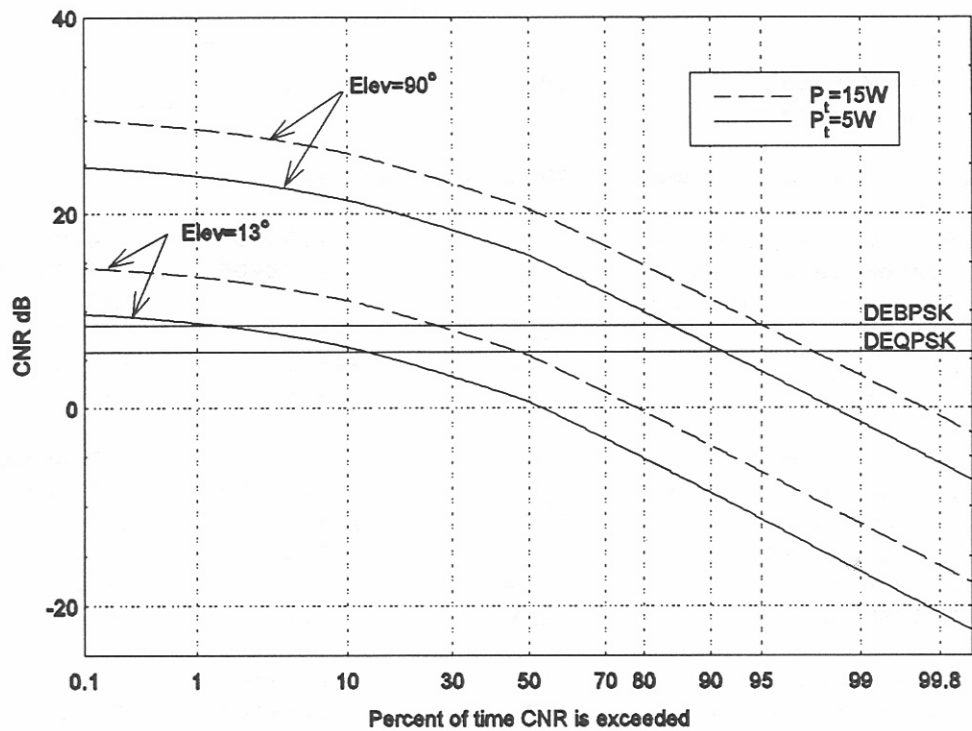


Figure A-1. Cumulative distribution of CNR for a business noise environment with the low-end receiving system.

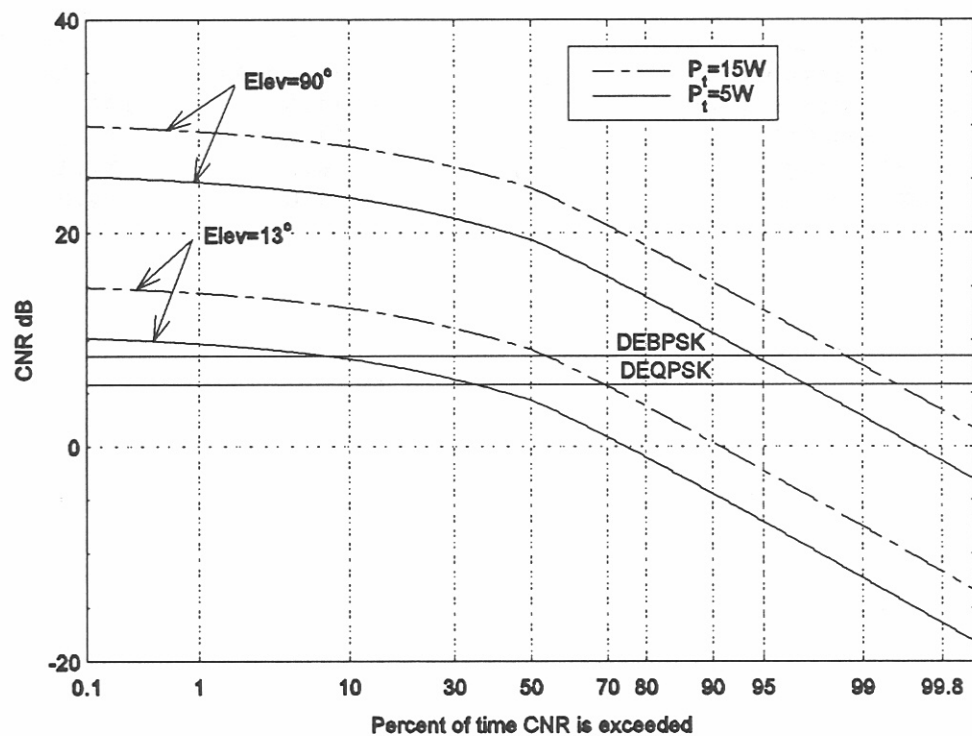


Figure A-2. Cumulative distribution of CNR in a residential noise environment with the low-end receiving system.

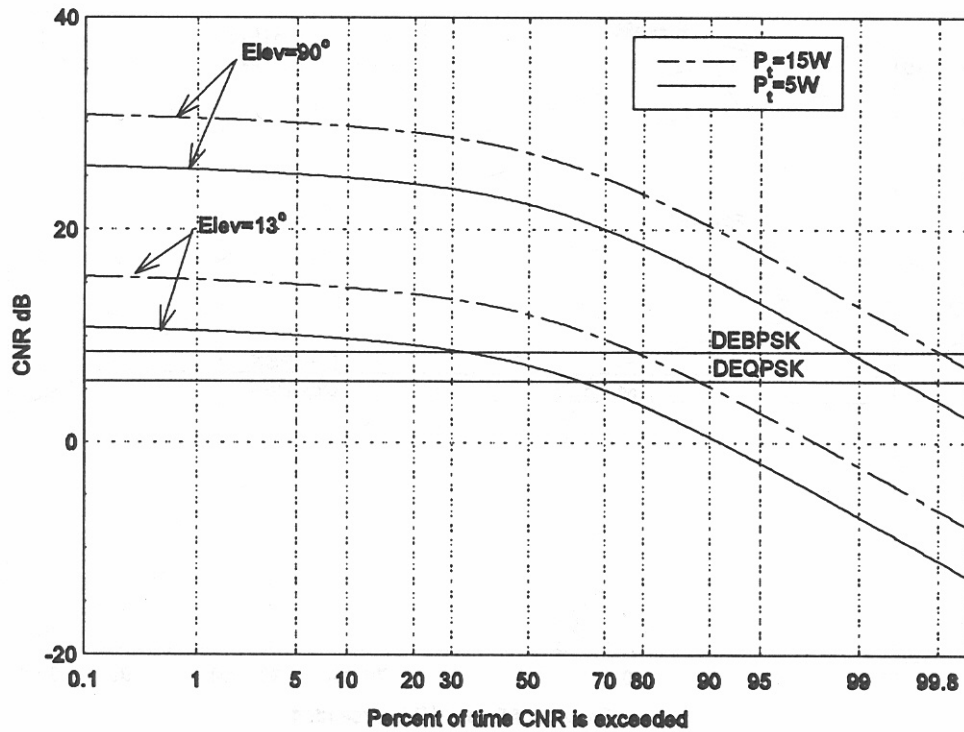


Figure A-3. Cumulative distribution of CNR in a rural noise environment with the low-end receiving system.

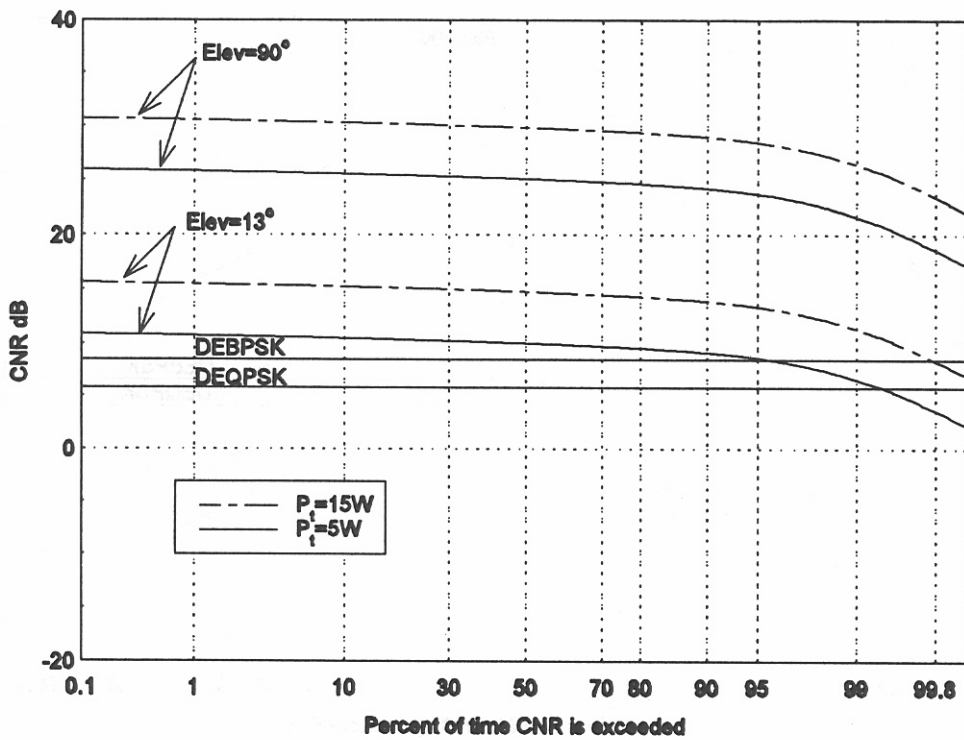


Figure A-4. Cumulative distribution of CNR in a quiet rural noise environment with the low end receiving system.

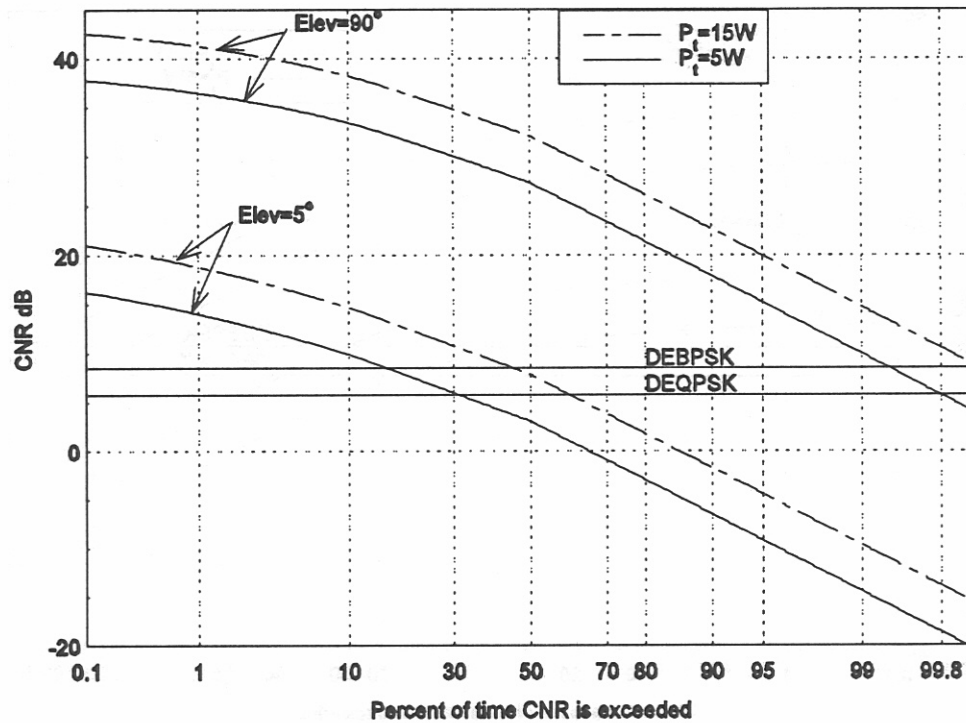


Figure A-5. Cumulative distribution of CNR in a business noise environment with the high-end system.

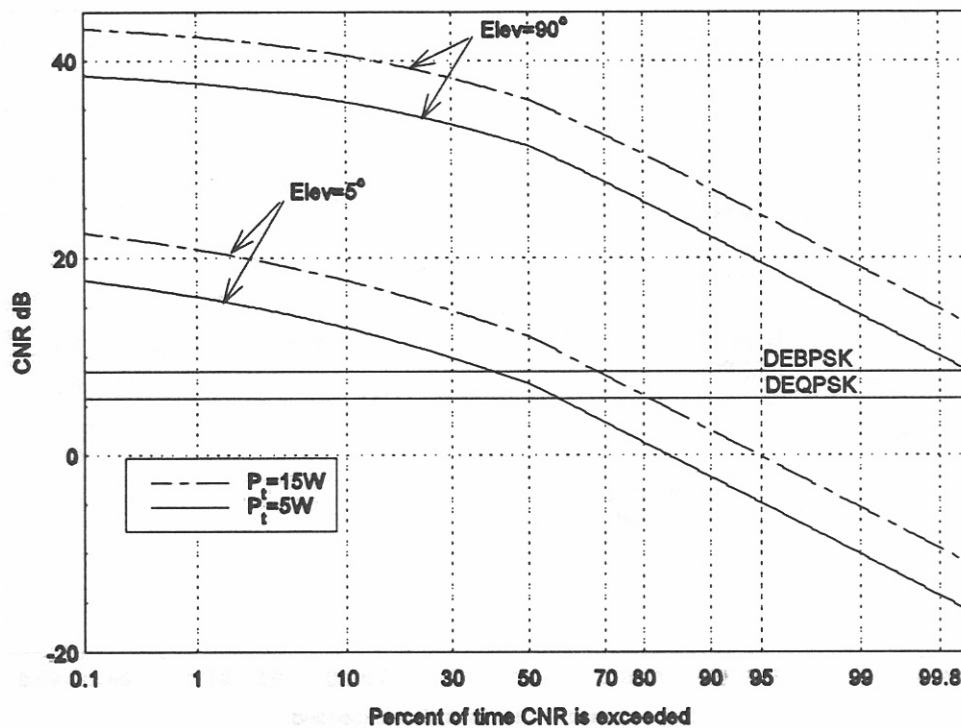


Figure A-6. Cumulative distribution of CNR in a residential noise environment with the high-end receiving system.

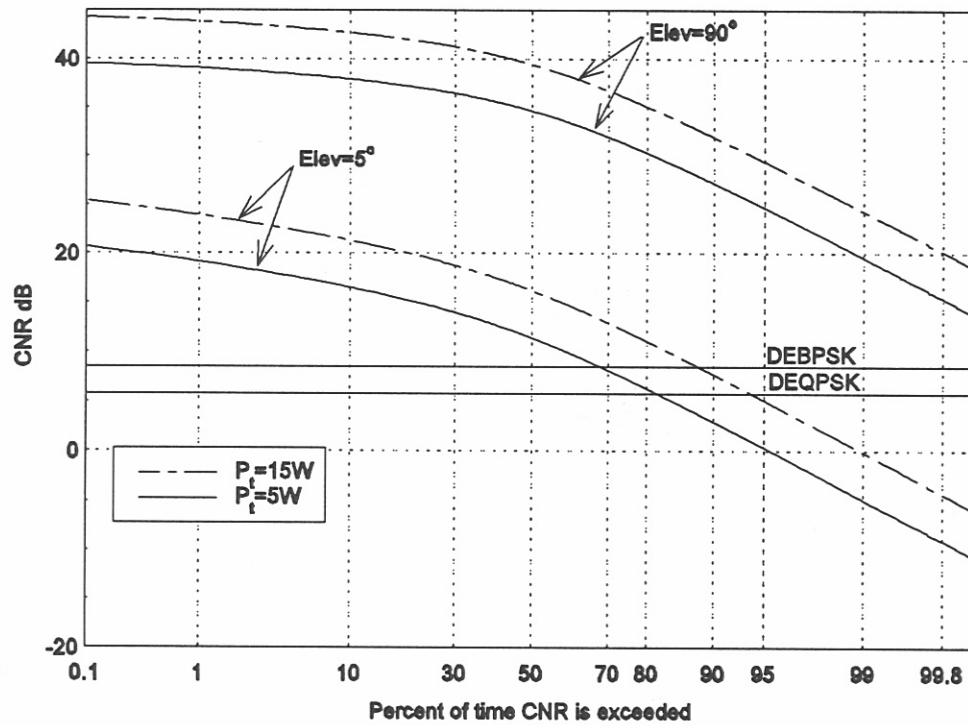


Figure A-7. Cumulative distribution of CNR in a rural noise environment with the high-end receiving system.

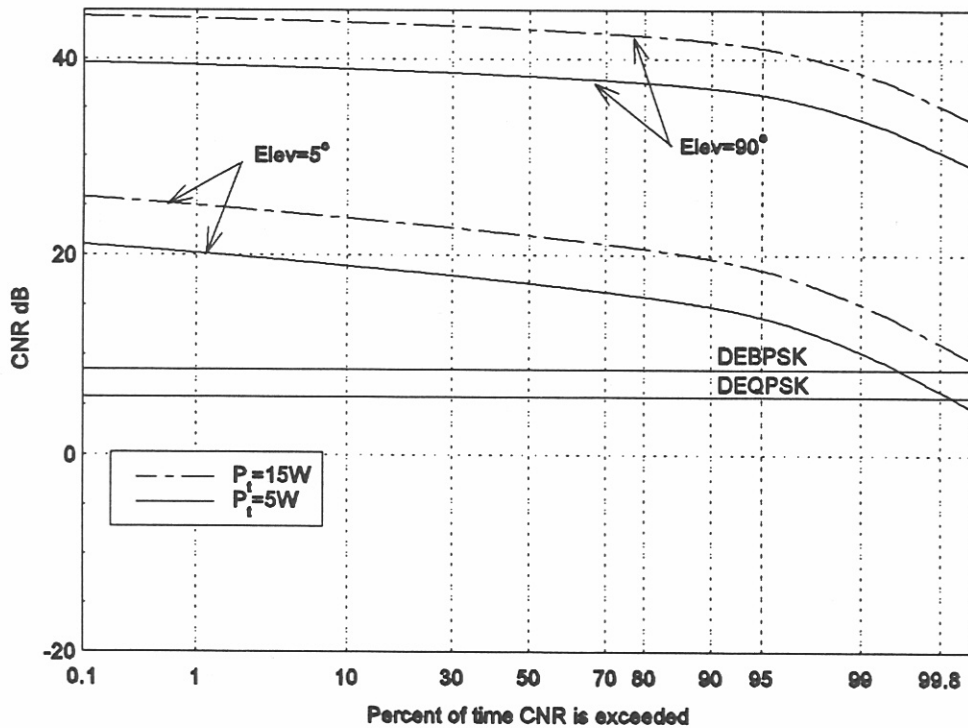


Figure A-8. Cumulative distribution of CNR in a quiet rural noise environment with the high-end receiving system.

